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providing positive and trouble free engagement and power-shifting operation.

**Brief Description of the Drawings**

5 In the accompanying drawings which form part of the specification:

Figure 1 is a perspective section view showing a preferred embodiment of a gear-clutch assembly.

Figure 2 is a partially exploded perspective section view showing a gear assembly and an electromagnetic actuator assembly.

10 Figure 3 is a perspective section view of a gear.

Figure 4 is a perspective section view of a hub.

Figure 5 is a perspective section view of a hub cover.

Figure 6 is a perspective view of a key.

15 Figure 7 is an exploded perspective section view of a gear assembly.

Figure 8 is a perspective section view of the gear assembly.

Figure 9A is an exploded front perspective view of an internal ramp ring, an external ramp ring, and spring.

20 Figure 9B is an exploded rear perspective view of an internal ramp ring, an external ramp ring, and spring.

Figure 10 is an exploded perspective section view of the electromagnetic actuator assembly.

Figure 11 is a section view of the gear-clutch assembly with the keys disengaged with the gear.

25 Figure 12 is a section view of the gear-clutch assembly with the keys engaged with the gear.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

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Best Modes for Carrying Out The Invention

As shown in Figures 1 and 2, a preferred embodiment of the invention, generally referred to as a gear-clutch assembly 1, comprises a gear assembly 2 and an electromagnetic actuator assembly 3.

The gear assembly 2 further comprises a gear 10, a needle bearing 11, a hub 12, a hub cover 13, a spring 14, an internally splined ramp ring 15, an externally splined ramp ring 16, a set of keys 17 and a set of coil springs 18.

The electromagnetic actuator assembly 3 comprises a base ring 20, an electrical coil 21, a case 22, a plunge ring 23, a sleeve 24, a case holder 25, a bearing holder 26 and a ball bearing 27.

As shown in Figure 3, the gear 10 is has two inner cylindrical surfaces, a first inner cylindrical surface 10a and a second inner cylindrical surface 10b. The first inner cylindrical surface 10a defines a plurality of axial grooves 10c that engage the set of keys 17. The second inner cylindrical surface 10b seats with an outer surface 11a of the needle bearing 11, which provides support for the gear 10.

As shown in Figure 4, the hub 12 has a stepped outer surface including a first outer cylindrical surface 12c, a second outer cylindrical surface 12d, and a third outer cylindrical surface 12e. Second and third outer surfaces 12d and 12e define a plurality of axial grooves 12k that are open at an end face 12j and receive the set of keys 17. The first outer surface 12c seats with an inner surface 11b of the needle bearing 11 to support the bearing 11 and gear 10. The hub 12 also has a stepped inner surface including a first inner cylindrical surface 12a, a second inner cylindrical surface 12b, and a third inner cylindrical surface 12g. Second inner surface 12b defines a plurality of spline grooves 12h that extend axially about half the length of the inner surface 12b for engaging the externally splined ramp ring 16. As shown in Figures 11

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and 12, the inner surface 12a of hub 12 engages a mating surface 31 of a supporting shaft 30, preferably with a sliding fit.

As shown in Figure 5, hub cover 13 has a cover plate 13a and a spindle 13b extending axially from the center of the plate 13a. When assembled, the plate 13a is mounted with appropriate means, such as fasteners or welding, to the end face 12j of the hub 12 to secure the spring 14, the internally splined ramp ring 15, externally splined ramp ring 16, and set of keys 17 within the hub 12. An annular protrusion 13e extending from the face 13f of the cover plate 13a mates with the hub 12 to properly position the hub cover 13 during assembly. Hub cover 13 also has an inner cylindrical surface 13c that engages the mating surface 31 of the supporting shaft 30, preferably with a sliding fit. A snap ring groove 13g receives a snap ring 28 to secure the electromagnetic assembly 3 to the gear-clutch assembly 2, as shown in Figure 1.

As shown in Figure 6, each key 17 has top surfaces 17a and 17b connected by a ramp surface 17c. The bottom surface 17f of the key 17 define recesses 17d and 17e for receiving coil springs 18.

As shown in Figures 9A and 9B, the internally splined ramp ring 15 is a cylindrical ring with internal splines 15c. The internally splined ramp ring 15 has a flat end face 15a and an arcuately shaped end face 15b defining three sets of bi-directional helical ramping surfaces that mate with the externally splined ramp ring 16.

The externally splined ramp ring 16 is a cylindrical ring with external splines 16c. The externally splined ramp ring 16 also has a flat end face 16a and an arcuately shaped end face 16b defining three sets of bi-directional helical ramping surfaces that mates with corresponding ramping surfaces of the end face 15b of ramp ring 15.

As shown in Figures 7-8, to assemble the gear assembly 2 the internally splined ramp ring 15, externally splined ramp ring 16, the spring 14, the set of keys 17, and coil springs 18 are assembled inside

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of hub 12 and secured with hub cover 13. The internally splined ramp ring 15 is inserted into hub 12 until the flat end face 15a seats against the annular surface 12i of hub 12 (Figure 4). The outer diameter of the ring 15 is sized to have a sliding fit with the hub 12 so that the ring 15 can rotate within the hub 12. When fully assembled, the internal splines 15c engage corresponding external spines 32 on the supporting shaft 30 to rotationally fix the internally splined ramp ring 15 with the supporting shaft 30. The externally splined ramp ring 16 is inserted into hub 12 so that the ramping surfaces of end face 16b mates with the ramping surfaces of end face 15b of the internally splined ramp ring 15. The external spline 16c of the externally splined ramp ring 16 is fitted into the internal spline 12h of hub 12 to rotationally fix the externally splined ramp ring 16 with the hub 12. However, the externally splined ramp ring 16 can move axially inside of hub 12. The inside diameter of the ramp ring 16 is sized to have a sliding fit with the supporting shaft 30 so that the ramp ring 16 can rotate around the shaft 30.

Spring 14 is inserted into the hub 12 so that, when fully assembled, the spring 14 is positioned between the cover plate 13a of hub cover 13 and the externally splined ramp ring 16. Spring 14 biases the externally splined ramp ring 16 axially, thereby firmly pressing the ramp ring 16 against the internally splined ramp ring 15. When assembled, the spring 14 and ramp rings 15 and 16 function as a torsion impact load damping device. During operation, a torsion impact load is transmitted through hub 12 to supporting shaft 30 or vice versa during engagement, which will be described further below. This torsion impact load causes the two ramp rings 15 and 16 to rotate relative to each other. As the ramp rings 15 and 16 rotate, the ramping surface of end faces 15b and 16b axially move the ramp rings 15 and 16 away from each other, thereby compressing the spring 14. The ramp rings 15 and 16 will continue to rotate until spring 14 is fully compressed. This provides a damping effect against torsion impact loads that effectively

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lowers the impact loads on various coupled elements including: the ramp ring 15 and corresponding supporting shaft 30, the keys 17 and corresponding grooves 12k of the hub 12, and the gear 10 and a corresponding mating gear (not shown).

5           As shown in Figures 7 and 8, each key 17 is inserted into a corresponding groove 12k of the hub 12 so that the key 17 is confined both in circumferential and axial directions by groove 12k and by the hub plate 13a of hub cover 13. There is a key 17 for each open-end groove 12k. The coil springs 18 are inserted in each recess 17d and 17e of  
10   each key 17. The springs 18 bias the key 17 to move outwardly from its retracted position at the bottom of the grooves 12k to an engaged position with corresponding grooves 10c of the gear 10. Finally, the plate 13a is mounted to the end face 12j of the hub 12 to secure the spring 14, the internally splined ramp ring 15, externally splined ramp  
15   ring 16, and set of keys 17 within the hub 12.

It is important to note that the number of grooves 10c on the inner surface 10a of the gear 10 is different from the number of keys 17 in the grooves 12k of the hub 12. The number of keys 17 is evenly divisible by the difference between the number of keys 17 and the number of  
20   grooves 10c on the inner surface 10a of the gear 10. For example, in the embodiment shown in Figure 1, the number of keys 17 in hub is 15 and the number of grooves on the inner surface of the gear is 12. Thus, for any given angular alignment between hub and gear there will always be  $(15-12=3)$  three keys 17 aligning respectively with three grooves 10c  
25   and receivable by these grooves.

Also, the width of grooves 10c is wider than the width of key 17 such that at any angular alignment between the gear 10 and hub 12 there will always be at least one key 17 that will align and be received by at least one groove 10c on the inner surface of the gear 10.

30           The engagement between hub 12 and gear 10 is controlled and actuated by the electromagnetic actuator assembly 3, as shown in

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Figure 10. The electromagnetic actuator assembly 3 comprises a base ring 20, an electric coil 21, a case 22, a plunge ring 23, a sleeve 24, a case holder 25, a bearing holder 26 and a ball bearing 27.

5 The base ring 20 is an annular ring with an inner rim 20a extending from inner perimeter and terminating with an angled face 20b. The base ring 20 seats against a front face 21a and an inner surface 21b of the electrical coil 21. An outer surface 24a of the sleeve 24 seats against an inner surface 20c of the base ring 20 to provide a bearing surface 24b for engaging the plunge ring 23.

10 The case 22 is an annular ring with an L-shaped cross section that seats against a back face 21c and an outer surface 21d of the electrical coil 21 and attaches to the base ring 20 by an appropriate means, such as welding or an interference fit. In this way, the base ring 20, case 22, and sleeve 24 create a housing around the electrical coil 21  
15 that mates with the plunge ring 23.

The plunge ring 23 is an annular ring with a stepped rim projecting from the inner perimeter for mating with the base ring 20, case 22, and sleeve 24. The stepped rim has a first outer surface 23a and a second outer surface 23b connected by a ramp 23c. The outer diameter  
20 of the second surface 23b is appropriately sized to have a sliding fit with the bearing surface 24b of the sleeve 24. When fully assembled, the plunge ring 23 can move freely along the axial direction relative to the hub 12 as the electrical coil 21 is energized and de-energized.

The case holder 25 is a plate 25a having a rim 25b extending  
25 from the outer perimeter of the plate 25a and defining a bore 25c. The rim 25b engages an outer surface 22b of the case 22 with an appropriate means, such as an interference fit or welding. A bearing holder 26 is mounted to the plate 25a about the bore 25c to secure a ball bearing 27 for supporting the actuator assembly 3 on the hub cover 13  
30 of the gear-clutch assembly 2. An inner surface 27a of the ball bearing 27 is axially fixed to and supported by the spindle 13b of the hub cover

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13. To further secure the actuator assembly 3, a snap ring 28 is inserted into the snap ring groove 13g of the spindle 13.

Once the gear assembly 2 and actuator assembly 3 are assembled to form the gear-clutch assembly 1, the gear-clutch assembly 1 is mounted to a supporting shaft 30 as shown in Figures 11 and 12. The gear selector 1 slides over the supporting shaft 30 until the internally splined ring 15 engages corresponding splines 32 of the supporting shaft 30 to rotationally fix the ring 15 with the shaft 30. Therefore, in the illustrated embodiment the ring 15 serves as the sole mechanical connection between the gear assembly 2 and the shaft 30. The actuator assembly 3 is rotationally fixed with an appropriate means.

In operation, the electrical coil 21 energizes and de-energizes to respectively disengage and engage the gear 10 with the supporting shaft 30. As shown in Figure 11, when the electric coil 21 is energized, an electromagnetic field forms in the air gaps between the case 22 and the plunge ring 23 and between the base ring 20 and the plunge ring 23. The electromagnetic field moves the plunge ring 23 toward the electric coil 21 closing the air gaps between the base ring 20, the case, and plunge ring 23. As the plunge ring 21 is moving toward the electric coil 21, it pushes the keys 17 along their ramp surfaces 17c and forces the keys 17 into the grooves 12k in the hub 12, thereby disengaging the gear 10 from the shaft 30,

As shown in Figure 12, when electric coil 21 is de-energized, the plunge ring 23 retracts back and moves away from the electric coil 21 by at least one key 17 that is urged outwardly from its retracted position to the engagement position by springs 18. As mentioned above, in the engagement position the keys 17 insert into corresponding grooves 10c of the gear 10, thereby engaging the gear 10 with the shaft 30. In this position, rotational forces are transferred from the supporting shaft 30 to the gear 10 or vice versa. In the present embodiment, when de-energized, there will always be at least three keys 17 that are urged

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outwardly from their retracted positions and pushing the plunge ring 23 axially away from the electric coil 21.

During engagement, if the speeds of the hub 12 and gear 10 are not synchronized, there will be an impact load exerted on shaft 30. As  
5 mentioned above, spring 14 and ramp rings 15 and 16 substantially reduce the torsion impact load.

The embodiment shown here is to disclose the invention. It by no means restricts the scope of the invention.